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Exploring Wireless: A Comprehensive Review on Sensor Node Integration and Energy Optimization Strategies for Enhanced Environmental Data Collection

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ABSTRACT

WSNs encompass a multitude of spatially distributed sensor nodes or devices employing radio signals for communication. Positioned strategically in a geographical area, these sensor nodes operate independently to collect information from their surroundings. Given their often remote and inaccessible locations, human interaction with deployed sensor nodes is limited. The core function of sensor nodes in WSNs involves sensing environmental data and transmitting it to a centralized base station or sink node. Subsequently, the collected data undergoes analysis, demonstrating the vital role of WSNs in facilitating data-driven insights within the realm of computer science. In this paper review of different research paper on the based of wireless sensor networks technology and different sensors for optimization of energy dissipation.

KEYWORDS: *Particle Swarm Optimization (PSO), Sensor Networks, Wireless Sensor Networks, LEACH*

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1. INTRODUCTION

One issue that has arisen around the world is that of energy efficiency, that is, it refers to the intelligent consumption of energy because most of the energy sources are finite, and what is sought is to have a consumption of energy. responsible in the present so that future generations can continue to enjoy them. According to different studies carried out, a considerable increase in the demand for residential electricity is expected within the following decades, so that our traditional electricity networks will not be able to meet the requirements of the 21st century [1-3]. But there have been two major drawbacks for these energy management systems: the large number of residential homes without adequate automation systems that are efficient and the high cost of implementing them [4-7]. For this reason, for this type of energy management, changes will have to be made in terms of the way in which energy is supplied, and the form of the energy market [8], which requires different types of networks, such as they are wireless sensor networks, as well as different energy management systems within smart homes. This article focuses on the implementation of these energy management systems using wireless sensor networks, which by maximizing coverage as a basis will allow better and more extensive services to users. It should be noted that this corresponds to the issue of smart grids, which through the use of smart meters, sensors and different actuators will allow obtaining more detailed information on the consumption of each residential area, and even obtain individual consumption. of each of the electrical and electronic devices within a specific dwelling, with which you can have a remote control of them [9]. We can also mention that wireless networks currently play a very important role in the improvement of technology and our quality of life, because they allow us to have a

great freedom to communicate with the world at any time and anywhere [10-12].

Although very advanced signal processing algorithms exist and have been adopted by the wireless sensor networks, most analytical studies on the coverage of these networks are carried out in excessively simplistic models, as is the case of the disk model, which does not capture the stochastic nature of detection [4]. This disk model has been analyzed several times and its limitations in obtaining optimal results has been understood and it has provided key information for the design of wireless sensor networks that in some cases have adopted algorithms of data fusion [8]. While on the other hand, studies have been carried out taking into account the problem of coverage in the wireless networks of sensors, which is similar to some computational geometry problems. For this reason, due to its special geometrical properties, the Voronoi algorithm has been used in this field of wireless sensor network research, especially in the problems related to the coverage of the sensors. Some authors have come to use this algorithm to propose repair methods based on triangular mesh models [9]. In addition, with the implementation of this algorithm some of the problems related to coverage have been solved, that is to say, it is possible to obtain a fairly good coverage of the sensors. However, there is little research on each Voronoi polygon, formed by the corresponding points to reach maximum coverage [10-14].

It is a method that can be widely used in the wireless sensor networks in order to solve the problems of coverage and low accuracy in locating the centroids [15]. A coverage strategy based on regions and different parameters is proposed, such as distance of coverage, capacity and percentage of coverage. It should also be noted that in comparison with traditional centroid algorithms, the proposed strategy offers some advantages, such as less localization error, less time consumption, greater optimization and better stability with respect to location.

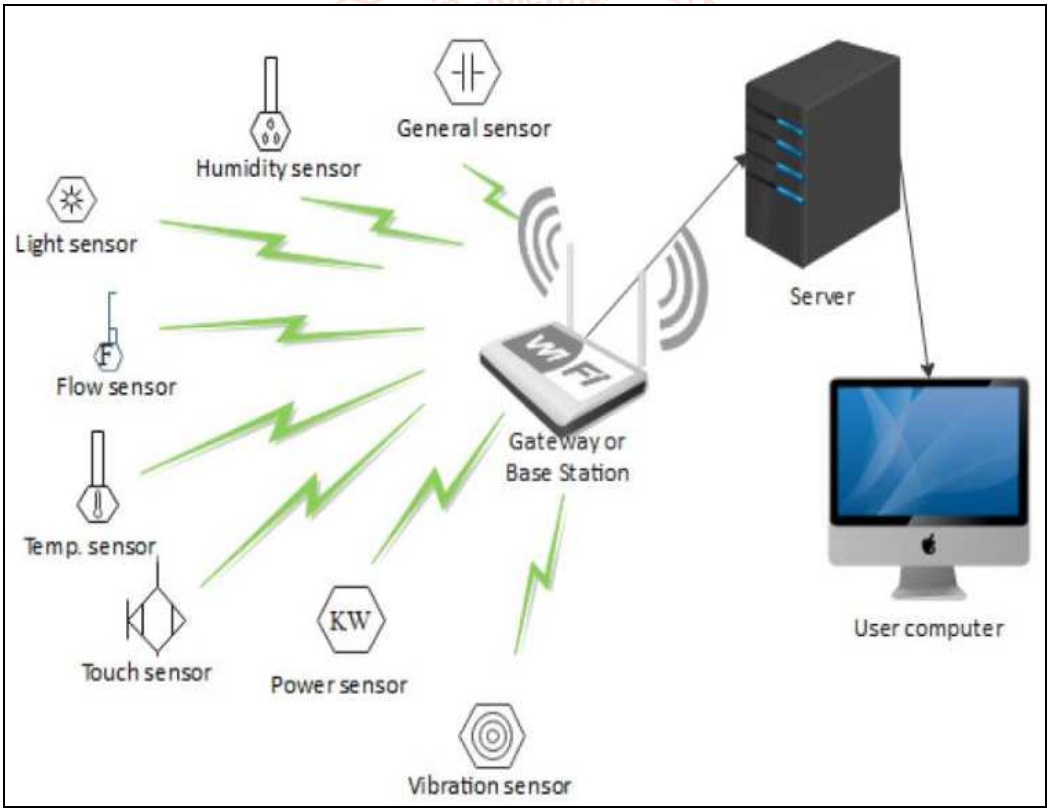

Figure 1.1: Wireless sensor network for indoor infrastructure

2. LITERATURE REVIEW

SonamMaurya, in paper "Hybrid Routing Approach for Heterogeneous Wireless Sensor Networks using Fuzzy Logic Technique", proposed a fuzzy logic technique. The proposed fuzzy logic technique is used with region-based clustering technique for cluster head selection. The technique reduces the overall consumption of energy in route selection process by implementing the fuzzy information.

Wendi Rabiner Heinzelman, in paper "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," proposed a protocol with rotation of cluster base station. Communication protocols have significant impact on the overall energy dissipation of these networks. Based on our findings that the conventional protocols of direct transmission, minimum-transmission-energy, multihop routing, and static clustering may not be

optimal for sensor networks, we propose LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network. LEACH uses localized coordination to enable scalability and robustness for dynamic networks, and incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. Simulations show that LEACH can achieve as much as a factor of 8 reduction in energy dissipation compared with conventional routing protocols.

LEACH is a clustering-based routing protocol that minimizes global energy usage by distributing the load to all the nodes at different points in time. LEACH outperforms static clustering algorithms by requiring nodes to volunteer to be high-energy cluster-heads and adapting the corresponding clusters based on the nodes that choose to be cluster-heads at a given time. At different times, each node has the burden of acquiring data from the nodes in the cluster, fusing the data to obtain an aggregate signal, and transmitting this aggregate signal to the base station. LEACH is completely distributed, requiring no control information from the base station, and the nodes do not require knowledge of the global network in order for LEACH to operate. Distributing the energy among the nodes in the network is effective in reducing energy dissipation from a global perspective and enhancing system lifetime. Specifically, simulations show that LEACH reduces communication energy by as much as 8x compared with direct transmission and minimum transmission-energy routing. The first node death in LEACH occurs over 8 times later than the first node death in direct transmission, minimum-transmission-energy routing, and a static clustering protocol, and the last node death in LEACH occurs over 3 times later than the last node death in the other protocols.

Wendi B. Heinzelman, in paper "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," proposed an architecture protocol with microsensors. Networking together hundreds or thousands of cheap microsensor nodes allows users to accurately monitor a remote environment by intelligently combining the data from the individual nodes. These networks require robust wireless communication protocols that are energy efficient and provide low latency. Low-energy adaptive clustering hierarchy (LEACH), a protocol architecture for microsensor networks that combines the ideas of energy-efficient cluster-based routing and media access together with application-specific data aggregation to achieve good performance in terms of system lifetime, latency, and application-perceived quality is developed and analysed. LEACH includes a new, distributed cluster formation technique that enables self-organization of large numbers of nodes, algorithms for adapting clusters and rotating cluster head positions to evenly distribute the energy load among all the nodes, and techniques to enable distributed signal processing to save communication resources. Research show that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multihop approaches. While designing a protocol, it is important to consider the function of the application, the need for ease of deployment, and the severe energy constraints of the nodes. These features led designing of LEACH, a protocol architecture where computation is performed locally to reduce the amount of transmitted data, network configuration and operation is done using local control, and media access control (MAC) and routing protocols enable low-energy networking.

Arati Manjeshwar and Dharma P. Agrawal, in paper "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks," proposed a hybrid protocol for enhancing the efficiency of network. Wireless sensor networks with thousands of tiny sensor nodes, are expected to find wide applicability and increasing deployment in coming years, as they enable reliable monitoring and analysis of the environment. A hybrid routing protocol (APTEEN) is proposed which allows for comprehensive information retrieval. The nodes in such a network not only react to time-critical situations, but also give an overall picture of the network at periodic intervals in a very energy efficient manner. Such a network enables the user to request past, present and future data from the network in the form of historical, one-time and persistent queries respectively. The performance of these protocols is evaluated and these protocols are observed to out perform existing protocols in terms of energy consumption and longevity of the network. Hybrid protocol APTEEN combines the best features of both proactive and reactive networks and provide periodic data collection as well as near real-time warnings about critical events. Though, our query model is suitable for a network with evenly distributed nodes, it can be extended further to sensor networks with uneven node distributions. We believe we have taken first step in defining an appropriate protocol for upcoming field of wireless sensor networks.

Mao YE, in paper "An Energy Efficient Clustering Scheme in Wireless Sensor Networks," proposed a

new clustering scheme. Data gathering is a common but critical operation in many applications of wireless sensor networks. Innovative techniques that improve energy efficiency to prolong the network lifetime are highly required. Clustering is an effective topology control approach in wireless sensor networks, which can increase network scalability and lifetime. Single-hop wireless sensor networks, which better suits the periodical data gathering applications. Though approach elects cluster heads with more residual energy in an autonomous manner through local radio communication with no iteration while achieving good cluster head distribution; further more, it introduces a novel distance-based method to balance the load among the cluster heads. Simulation results show that EECS prolongs the network lifetime significantly against the other clustering protocols such as LEACH and HEED.

Vivek P. Mhatre, in paper "A Minimum Cost Heterogeneous Sensor Network with a Lifetime Constraint," proposed a method for reducing cost in heterogeneous networks. A heterogeneous sensor network is considered in which nodes are to be deployed over a unit area for the purpose of surveillance. If an aircraft visits the area periodically and gathers data about the activity in the area from the sensor nodes. Nodes act as the cluster heads besides doing the sensing. Nodes use multihopping to communicate with their closest cluster heads. The optimum node intensities and node energies guarantee a lifetime of at least T units, while ensuring connectivity and coverage of the surveillance area with a high probability. The overall cost of the network is minimized under these constraints. Lifetime is defined as the number of successful data gathering trips (or cycles) that are possible until connectivity and/or coverage are lost. Conditions for a sharp cutoff are also taken into account, i.e., we ensure that almost all the nodes run out of energy at about the same time so that there is very little energy waste due to residual energy. Vivek Mhatre considers two types of hierarchical sensor networks: one that uses random uniform deployment and the other that uses grid deployment. This approach involves using two types of nodes: type 0 nodes which do the sensing and relaying on the ground. He also ensures conditions for connectivity and coverage of the area during the lifetime of the network. The fact is that the cluster heads as well as the nodes within one hop of the cluster heads, i.e., the critical nodes have the maximum relaying burden and, therefore, these nodes are likely to run out of battery before other nodes. The overall cost of the network is minimized satisfying these constraints.

3. COMPARISON WITH TRADITIONAL NETWORK

Routing is one of the most important and challenging task of a network and so is for wireless sensor network. Routing in wireless sensor network is very challenging and different than from other traditional networks due to the following reasons listed below [15-20]:

- **Global Addressing Scheme***:* Since the number of nodes in sensor network is much higher than other ad-hoc networks, it is not possible to build global addresses to sensor nodes. The classical IP-addressing mechanism cannot be applied to sensor network; hence the routing protocols that work based on IP-addressing cannot be used with sensor network.
- **Multi-Point Communication:** Most of the application in sensor network requires the sensed data from multiple sensor nodes to a sink, which is in contradiction to our traditional networks which require point to point communication.
- **Data Redundancy:** A sensing region consists of number of nodes and many a time's multiple sensors generate similar data which has significant amount of redundancy in it. This redundant data can cause power exploitation, which is a valuable resource of sensor network. Hence, this data redundancy is needed to be reduced for improving the efficiency of the network.
- **Constrained Resources:** Sensor networks are very much constrained in terms of energy resources, computation capacity and memory capacity hence requires careful resource management.

4. APPLICATIONS OF WSN

Wireless Sensor Networks are formed by tiny sensing devices for wireless communication, actuation, control and monitoring. Given the potential benefits offered by these networks like simple deployment, low cost, lack of cabling and mobility they providing numerous applications among which some are categorized below:

Disaster Relief Operations: The WSN framework structural planning for flood forecasting comprises of sensors (which sense and gather the information applicable for counts), a few nodes alluded to as computational nods and a manned focal checking office (which checks the results with the accessible online data, executes an incorporated rendition of the forecast calculation as an excess system, issues cautions and starts departure strategies). Diverse sorts of sensors are obliged to sense water release from dam, precipitation, stickiness, temperature, and so on.

The information gathered by these sensors are utilized within the flood prediction calculation. The computational nodes have compelling CPUs needed to execute the appropriated expectation model. The computational nodes should impart the forecast results to the observing node. They additionally have correspondence between themselves for discovering breaking down of nodes [21].

Intelligent Buildings/Bridges: To reduce the energy use of buildings, WSNs could be deployed to measure temperature, humidity and air flow, which then could be used to adapt the temperature within the building automatically. Also sensors could be used to monitor the mechanical stress level of buildings, such as bridges, to find out the likelihood of a collapse [22].

Biodiversity Mapping: WSNs can be used, for example, to monitor the erosion processes on the ground of the ocean. Closely related is biodiversity mapping in which a number of plants or animals in a certain region are monitored [83].

5. CONCLUSION

In the conclusion of this study, several critical points were considered. Clustering emerged as a pivotal technique for mitigating energy dissipation in the network and augmenting its stability. Given that nodes may be located far from the Base Station (BS), direct communication becomes impractical due to limited battery capacity, necessitating energy-efficient alternatives. Numerous clustering protocols, such as LEACH, have been designed to address this issue. LEACH, as a fundamental algorithm, employs a procedure of clusterhead election, where each sensor node generates a random number in each round. If this generated random number falls below a predefined threshold, the respective node is elected as the clusterhead for the current round. This approach offers a dynamic and distributed means of forming clusters, thereby optimizing energy consumption and enhancing network performance.

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